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Propagation and Production of Native Aquatic Plants

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BACKGROUND: Aquatic system restoration often involves establishment or reestablishment of native aquatic plant communities. The role of plants in aquatic systems is significant: in addition to providing valuable fish and wildlife habitat (Dibble et al. 1996), aquatic plants can improve water clarity and quality (James and Barko 1990), reduce rates of shoreline erosion and sediment resuspension (James and Barko 1995), and help prevent spread of nuisance exotic plant species (Smart and Doyle 1995). Efforts to restore beneficial aquatic plant communities are best concentrated on establishment of small, protected plant colonies at strategic locations within unvegetated reservoirs (Smart and Dick 1999). Once successfully established, these plants serve as founder colonies, which will spread beyond their protective borders to adjacent, unvegetated areas of the reservoir when conditions are favorable.

Each restoration project usually requires many individuals of several aquatic plant species. Because acquisition of large numbers of appropriate plant propagules in a timely manner can be difficult, the authors have begun developing methods for producing their own transplants, tailored to each specific project.

Although commercial suppliers may provide some of the plant materials needed for a restoration project, propagule production may be preferred for several reasons. Currently, only a limited selection of aquatic plant species (particularly submersed plant species) is readily available from commercial sources. Propagule types offered are also frequently unsuited to the demands of plant establishment in large water bodies. For the most part, stem fragments, seeds, root crowns, or dormant perennating organs (tubers, winterbuds) are sold commercially. These propagules are weak, and require near-ideal conditions for successful establishment. In the harsh environment of artificial reservoirs, most are destined to fail. Additionally, such propagules are often only available at certain times of the year, very possibly at the wrong time of the year for a particular restoration project. As an example, northern suppliers generally must wait until spring thaws occur, which may be beyond the period for optimal establishment in southern reservoirs.

Plant origin may be an issue as well. Although a particular species may be found throughout the United States, there may be pertinent genetic variability among plants from different regions. For instance, a northern variety may not do well in southern climates. Finding source plants locally (or as locally as possible) is highly recommended.

For the above reasons, the authors recommend finding local plant stocks and cultivating desired species to produce mature transplants (potted plants) for many restoration efforts. These propagules are much more likely to survive harsh environmental conditions faced when transplanted into reservoirs and lakes. Included in this technical note are some general requirements and considerations for the culture of a variety of aquatic plants, including submersed, floating-leaved, and emergent growth forms. A more specific treatment of this information is given in Smart and Dick (1999).

FACILITIES FOR OFF-SITE PRODUCTION: Production of aquatic plants requires adequate facilities, but these need not be complicated or expensive. Small ponds, tanks, or raceways may be used to grow aquatic

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plants. To minimize transportation costs, and the possible damage that occurs during transport of plant materials, production facilities should be as close as possible to the restoration site.

Ponds offer excellent sites for culturing aquatic plants. Although any pond that has a reliable water source (and water depth) will suffice, those in which drainage and filling are easily accomplished serve best. This allows the plant grower to manipulate water levels for cultivation needs such as planting, weeding, fertilizing, and harvesting. Because the objective is to produce robust, potted transplants, the goal is to restrict growth to the containers. Open pond bottom sediments allow growth of endemic vegetation and encourage escape of cultivated plants. Both of these situations are undesirable because plants growing wild in the pond reduce potential growth of potted plants by competition and interfere with maintenance and harvesting operations. For these reasons, lined ponds are preferred over earthen ponds. Construction of concrete pads on earthen pond bottoms offers the same advantage.

Segregation of plant species within a lined pond can be critical for successful cultivation of many species. Cross-contamination by faster (or earlier) growing species can reduce production of slower (or later) growing plants. Because many aquatic plants spread vegetatively from fragments, care must be taken when selecting species for polyculture within a single pond. Isolating fragment-spreaders (or prolific seed producers) in their own pond is highly recommended. A second option is to construct enclosures for these species. Fine-mesh shade cloth fencing will serve to prevent spread by fragmentation of all species of aquatic plants discussed in this manual.

Tanks are excellent vessels for growing aquatic plants. The advantages of tank culture include: accessibility, water quality management, and separation of species. Many sizes and shapes of fiberglass and plastic tanks are available commercially. While these are generally manufactured for the aquaculture of fish and invertebrates, some models are well-suited for culturing aquatic plants. When selecting tanks, ensure that tank depth is suitable for the species of plants to be cultivated. Another consideration is tank dimension. Easy access is critical to good plant cultivation. A tank width of about 1 m may be the maximum for easy access to plants. For many species of submersed and floating-leaved plants, tanks in the range of 0.5 to 1.0 m deep by 1.0 m wide by appropriate length (5 or more m) are recommended. For ease of operation, tanks should be accessible from both sides. Shallow tanks (25 cm or less) are suitable for emergent species, as long as the entire growing container (pot) can be covered with water.

Construction of custom tanks may be desirable and cost-effective on many projects. For long-term cultivation, concrete vats can be made to size for specific plant types. Permanent plumbing, including filling and drainage piping, can be included in such structures. Less expensive, custom tanks can be constructed from available building materials (lumber or concrete blocks) and pond liner material.

Excessive solar heating can be a serious problem, especially in above-ground tanks. Hot, sunny days may cause excessively high temperatures within tank cultures, and plants may suffer high mortality. Because excessive light can also damage submersed aquatic plants, the authors recommend covering tanks with a light grade (30-50 percent reduction of sunlight) shade cloth. This will reduce both light intensity and temperature. Shading for floating-leaved or emergent species is not recommended.

PLANT GROWTH REQUIREMENTS: The key to growing any plant is to provide conditions that allow the plant to fulfill its need for nutrients and sustain a rate of photosynthesis sufficient to provide for respiration and growth. Successful culture of rooted submersed aquatic plants will thus depend on the ability to provide adequate nutrients via the sediment to the plant roots and adequate levels of light and inorganic carbon via the water to the plant shoots (Smart and Barko 1985).

Substrate. Fine-textured substrates with a low to moderate organic content (10-20 percent) are ideal for most species of submersed, floating-leaved, and emergent aquatic plants. Sandy substrates are often

unsuitable because they are generally infertile and added nutrients may diffuse into the water column, causing growth of unwanted algae. Highly organic substrates can be inhibitory to plant growth (Barko and Smart 1986). When available, fine-textured sediments from ponds or lakes in which aquatic plants are known to grow are recommended.

If the growth potential of sediments is in doubt, small-scale trials should be conducted to determine sediment suitability for supporting aquatic plant growth. Because suitable natural sediments may not always be available, the use of commercial potting soils or topsoils may be necessary. For relatively small-scale efforts, bagged soils may be practical. When selecting commercial potting soils for aquatic use, the lowest priced product may be the most suitable as it will generally contain the fewest additives. Avoid products that contain bulk additives such as peat, vermiculite, perlite, or sand. For large-scale projects, local topsoils may be purchased in bulk after ensuring their suitability.

Fertilization. For short-term (2 months or less) cultivation of submersed aquatic plants such as wild celery, *Vallisneria americana*, an initial fertilization of the potting medium is usually sufficient. Often, nitrogen must be added to achieve optimum growth (Smart and Doyle 1995). Rates of 1 g nitrogen per liter of potting medium are sufficient to support growth during this period. Nitrogen should be added as an ammonium salt, not as nitrate or urea, due to potential damage to plants.

Longer-term cultivation of submersed aquatic plants may require periodic fertilization or addition of other nutrients. Adding nitrogen as either ammonium or nitrate to the water column every few weeks will sustain the growth of mature transplants. Excess levels of nitrogen can be inhibitory to the growth of submersed aquatic plants, so concentrations should not exceed 1 or 2 mg/L.

Floating-leaved and emergent growth forms such as white water lily, *Nymphaea odorata*, and arrowhead, *Sagittaria latifolia*, generally produce more biomass than do submersed forms and have proportionately greater demands for nutrients. For this reason, larger quantities of fertilizer should be added to the sediment substrate. Because these forms have their photosynthetic and carbon uptake surfaces in the air rather than the water, excessive algal growth generally does not interfere with their growth. In fact, once they develop a canopy of leaves, these plants may shade out algae. Long-term growth of cultures of these growth forms can be sustained by adding nutrients directly to the water without concern. Although these growth forms generally are not well-adapted to absorb nutrients from the water, transpiration drives water and dissolved nutrients into the root mass. For this reason, pots with ample drain holes are preferable, so that the roots will be in close association with the water.

Water Quality. A reliable source of high quality water is required for growing submersed aquatic plants since floating-leaved and emergent species are less particular. Ideally, water should be clear and relatively nutrient-free (at least phosphorus-free). Clear water allows adequate light penetration for optimal growth, while nutrient-free water reduces the likelihood of algal blooms in the culture. The use of municipally treated water is not recommended, unless chlorine is first removed.

For tank cultures, lake water that has been polished or treated to acceptable quality is used. In one method, lake water was added to a vegetated pond, the vegetation serving to reduce turbidity and remove much of the dissolved phosphorus from the water column. In a second method, lake water was added to a lined pond and the water was treated with aluminum sulfate (approximately 0.1 kg per 1000 L) to flocculate clays and remove phosphorus by sorption onto precipitates, and mechanically filtered with sand filters (Dick et al. 1997).

Additional requirements for water that will be used to grow submersed aquatic plants include a source of inorganic carbon and a balanced chemical composition including calcium, magnesium, and potassium ions (Smart and Barko 1985). Periodic replacement of part of the water may be desirable to maintain favorable

levels of alkalinity, dissolved inorganic carbon, and dissolved ions. Alternatively, sodium or potassium bicarbonate and calcium (as either a sulfate or chloride salt) can be added to maintain adequate levels of these constituents.

Water Circulation and Mixing. In lined ponds or tanks, carbon dioxide availability may be a factor limiting growth of submersed aquatic plants, since floating-leaved and emergent species acquire carbon dioxide directly from the air. Consequently, aeration of tank cultures is recommended for submersed species. A regenerative blower/compressor aeration system is required to supply the air, and vigorous bubbling of atmospheric air through air stones usually provides adequate mixing in addition to supplying carbon dioxide.

Growing Containers (Nursery Pots). Blow-molded plastic nursery pots with drain holes in the bottom are recommended as growing containers for aquatic plants. These holes allow movement of dissolved nutrients into the sediment substrate where they can be taken up by the roots. Various sizes and shapes of commercial nursery pots are available. The authors have used both quart- (4-in. or 10-cm diameter) and gallon- (6-in. or 15-cm diameter) sized pots for growing a wide variety of aquatic plant species. Commercial-grade nursery pots can be reused several times.

Propagule Types. Stem fragments, daughter plants, root crowns, winterbuds, tubers, seeds, etc. are adequate as starter materials for plant propagule production in tanks or ponds. Commercial availability is often seasonal, and locality concerns should be carefully weighed. If local or regional populations of a particular species are known, these populations can be harvested to obtain starter propagules. Plant more pots than needed for a project if other projects are planned in the future. After a culture of a particular species is established, it can be used as a source for the next generation of cultivation.

Many aquatic plant species spread vegetatively from **stem fragments**. These species have apical meristems at the terminal ends of the shoots. Select stem tips and cut to a length of 15 to 20 cm. When selecting material, remember that the greater the density of leaves along the stem, the better, as most nodes can produce roots as well as leaves and branches. Plant the apical cuttings about 8 to 10 cm deep in the potting medium. For faster development, several cuttings should be planted in each pot.

Some aquatic plant species grow in a rosette form and produce **daughter plants** along stolons. To propagate these species, daughter plants should be clipped from the parent and planted directly into pots. These plants have a basal meristem and care must be taken not to cover this growing tip when planting. A relatively dense, firm substrate is important for these species because they are buoyant and, without sufficient anchoring, are easily dislodged from the potting medium.

Many aquatic plants perennate by producing **tubers** or **winterbuds** that survive winter or dry periods in a dormant state. Tubers or winterbuds are an excellent way to start a culture. Dormant propagules can be collected, held in a dormant state by refrigeration for up to six weeks, and then planted when desired.

Almost all of the aquatic plant species produce viable **seed**. However, the ease of propagation of most aquatic plants by other means and a rather limited knowledge of seed storage and germination requirements limit the usefulness of seed as a starting material for producing plant propagules. Seed- or sporeladen sediments (obtained from drained pond cultures) have been used to start plants of several annual species such as southern naiad (*Najas guadalupensis*), slender pondweed (*Potamogeton pusillus*), horned pondweed (*Zannichellia palustris*), and muskgrass (*Chara* spp.). Physically scarified seed are also the propagule of choice for American lotus (*Nelumbo lutea*).

PLANT CULTIVATION PROCEDURES: The general procedure for producing potted aquatic plants (mature transplants) is as follows:

- Fill pot to about 1/4 full (above the drainage perforations) with substrate.
- Add an appropriate dose of fertilizer.
- Fill the remaining 3/4 of the pot with substrate.
- Place pots in growing facility (pond, tank, etc.).
- Fill the growing facility to 10 or 15 cm above the pot with clean water to allow the substrate to become saturated. Apply pressure to consolidate the substrate, expressing any trapped air or water and eliminating voids. Add additional substrate if necessary.
- Allow the filled pots to "cure" for one to several weeks – particularly if using a non-aquatic substrate. An initial nutrient pulse is generally observed as some nutrients and organics are released into the water. This is evidenced by brown staining of the water by humic materials or by the presence of an organic film on the water surface. Flush the water and refill several times if necessary.
- Make an indentation in the center of the substrate.
- Plant the propagule, and backfill to ensure that the plant is anchored.
- Fill the tank or pond to the desired cultivation depth with clean water.

Culture Maintenance. In addition to periodic fertilization, water exchanges, and water circulation, cultivation of aquatic plants generally includes pest management. As with any culture or crop, nuisance weeds or pests may cause problems. Pond sediments often contain seeds and spores of aquatic species that might interfere with production of desired species. Although expensive and labor-intensive, sediments can be heat sterilized to avoid or reduce this problem. Hand weeding will be required to remove unwanted plants, but this also is time-consuming and labor-intensive. Inadequate separation of plant species in mixed pond or tank cultures can also lead to cross-contamination and "weed" infestations, especially where production of single-species transplants is critical. Growing monocultures in separate tanks will usually prevent cross-contamination.

Excessive algal growth is a common problem in cultures of submersed aquatic plants. Once algae become well-established in a culture, they are difficult to control, so prevention is prudent. Using low-nutrient water and avoiding excess fertilizer will usually prevent algal problems. Reduction of existing algal blooms may require exchanging the water with low-nutrient water and either hand removal of filamentous growths or filtering the water to remove phytoplankton.

Herbivore damage may become a problem in some situations. Pond cultures must be protected from turtles, carp, waterfowl, muskrats, and some invertebrates, generally by caging or fencing that effectively excludes grazers from the plants. In tank cultures, aphids and caterpillars can reach nuisance proportions, and may require chemical control.

CONCLUSIONS: Many restoration efforts have been thwarted by use of weak bare-root plants, seeds, or propagules from other areas of the country that are not adapted to local conditions. By using welldeveloped potted plants from local stocks in restoration projects, chances of long-term survival of desirable plant communities are greatly increased.

Research and experience have led to methods that maximize chances of success when growing aquatic plants for restoration projects. By developing proper facilities for plant production, furnishing adequate growing conditions and low-nutrient water sources, and maintaining cultures throughout the growing process, high-quality plants can be produced.

Judiciously harvesting local plant materials that are free of any exotic plants (and growing enough plants to harvest asexual propagules for subsequent projects) permits growers to become self-sufficient at the end of the first growing season, without having to rely on continual harvest from local wild populations.

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